Bringing Healthcare to Rural Ghana: The Impact on Engineerin

ANDREA KUBICKI, The Pavlis Institute for Global Technological Leadership

As a senior pre-medicine student at Michigan Technological University, I traveled to Ghana this summer through the Pavlis Institute for Global Technological Leadership. Before traveling, I worked with a team from the International Business Venture Enterprise and engineering senior design team to create a mobile health clinic. While in Ghana, my team introduced the mobile health clinic and went into the field to collect data on the use of the vehicle and ideas for improvement in the future.

Ms. Laura Lynn Lynch, Pavlis Institute for Global Technological Leadership

I am a fourth-year biomedical engineering/pre-medicine student at Michigan Technological University in Houghton, Mi. I traveled to Malta this past summer through the Pavlis Institute for Global Technological Leadership. While in Malta I completed service projects that both enhanced my leadership skills and provided me insights to the differences in learning outcomes associated with leadership and cultural literacy in developed versus developing countries.

Dr. Robert O. Warrington Jr., Michigan Technological University

Robert O. Warrington is currently Director of the Institute for Leadership and Innovation, which houses the highly interdisciplinary and innovative Enterprise program, the High School Enterprise program and the Pavlis Institute for Global Technological Leadership at Michigan Technological University. Dr. Warrington was Dean of the College of Engineering from 1996 to 2007 and was the founder and Director of the Institute for Micromanufacturing at Louisiana Tech University. Before joining Michigan Tech in 1996, he received his BS degree in Aerospace Engineering from Virginia Polytechnic Institute, his MS in Mechanical Engineering from the University of Texas at El Paso and his PhD in Mechanical Engineering from Montana State University. Dr. Warrington served in the US Army for two years and on the faculty at Montana State University for eight years. He was the head of the Mechanical and Industrial Engineering Department at Louisiana Tech University for 11 years, and was the Director of the Institute for Micromanufacturing from 1991-1996. Dr. Warrington was a founding advisory board member for the ASME Nanotechnology Institute. He is past VP for Education, Centers Sector of ASME. He currently leads the Vision 2030 study for the future of mechanical engineering education. He was a member of the Board of Directors for ABET after serving a number of years as a program evaluator, member of the Engineering Accreditation Council and the Executive Committee of the EAC. Dr. Warrington is chair of the Education Committee for the Pan American Federation of Engineering Societies (UPADI). Dr. Warrington is a Fellow of ASME and AAAS and is a member of the Pan American Academy of Engineering. He was an associate editor (now emeritus) for the ASME/IEEE Journal of Microelectromechanical Systems and has over 150 technical publications and numerous presentations (35 invited), and 49 research grants from foundations, government and industry. Dr. Warrington is the founder of the Commercialization of Microsystems Conferences, is a past founding president of MANCEF and currently is a member of the executive board for MANCEF. Dr. Warrington was an Associate Director for the Center for Wireless Integrated Microsystems, an NSF Engineering Research Center (2000-10). Dr. Warrington's research interests include MEMS (particularly micro heat transfer and fluid flow), micromanufacturing, energy scavenging at the microscale, and micromechanical machining processes.

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Introduction and Purpose

A mobile health clinic for use in rural Ghana was designed and built by Michigan Technological University undergraduate students from 2012-2013. The mobile clinic was designed and built through collaboration among students in the Pavlis Institute for Global Technological Leadership, an Enterprise team (a multi-disciplinary senior design team consisting of students from engineering, business, and the social sciences), and a mechanical engineering technology senior design team. The clinic was built for those who lack the means to visit healthcare centers in remote regions of Ghana; the clinic provides affordable treatment and basic diagnostics for these people living in remote areas.

The leadership institute that led the project is a 25-hour certificate program based on leadership, international experiences and pervasive development of professional skills – an area of particular need for the university's STEM students. The institute was initiated in 2005 to provide students with international leadership skills through coursework and a student-led international experience. The students work in multidisciplinary teams to prepare for their international experience. The majority (70%) of students are engineering, business, and science majors. The teams work to prepare technology projects for the year prior to their time abroad and then work on these projects while in country. Students check on completed projects for sustainability each year. Thus, some projects are continued while others are new. The mobile health clinic is an example of one of the projects developed by the leadership institute students that will be expanded, improved, and monitored well into the future.

The project started when a need for a mobile health clinic was first observed in the summer of 2012 by a group of institute students in Ghana. This team observed a lack of healthcare in the periphery villages on the outskirts of regional hospitals. The team returned with their observations and a graduate student, under the direction of one of the authors, developed the concept. Her report stated, "The Mobile Clinic will serve a niche market not currently met by existing mobile clinics and international aid work."[1] The 2013 team set out to accomplish serving this need during the next year.

The concept of mobile healthcare is not new; however, the mobile healthcare project discussed in this paper is unique in the sense that it was and continues to be student-led. Currently, there are a number of mobile healthcare initiatives in Africa. The Community Health Africa Trust (CHAT) travels by bicycle, foot, vehicle, and camel to villages in five remote countries of Kenya.[2] FHI360 outfitted minivans to serve in South Africa.[3] Another organization provided eight mobile health clinics to the Ghana Ministry of Health.[4] According to the local hospital director these clinics are set up for specialty services and cannot reach the very rural regions of Ghana. In addition, they are very expensive.

The student-led mobile health project differs from other engineering education projects in a few ways. The first difference is the fact that the project was and is student-led (mainly by engineering students) and these students learned valuable skills in cross-cultural communication and in developing a complete engineering design project in a developing country. The second difference is the close collaboration and communication with the doctors and medical staff in Ghana before and during development of the mobile health clinic. The field

testing of the mobile clinic was another unique aspect of this design project as was the close collaboration among the business, social science, and engineering/engineering technology students.

Design and Methods

The leadership institute team utilizing the previous cohort's information and the graduate student's report began to develop the mobile health clinic in the fall of 2012. Michigan Technological University donated a 12-passenger vehicle and a group of engineering and engineering technology senior design students prepared the vehicle for retrofitting. Shortly thereafter, fundraising began and the teams searched for used medical equipment for the clinic. The leader of the project was a mechanical engineering and biomedical engineering student who was involved with both the leadership institute and the enterprise. He acted as the liaison between the two groups.

The interior of the vehicle was redesigned to accommodate the following: lighting system, auxiliary power system, water supply system, two jump seats, refrigeration, microscopes, EKG machine, centrifuge, 6500W 4 stroke gasoline generator, awning, and portable ultrasound with a convex, transvaginal, and linear probe plus other incidentals.

Below, Fig. 1.1 shows the schematic of the interior of the vehicle. Fig. 1.2 shows a medical team in front of the vehicle in Ghana and Fig. 1.3 shows the clinic in action.

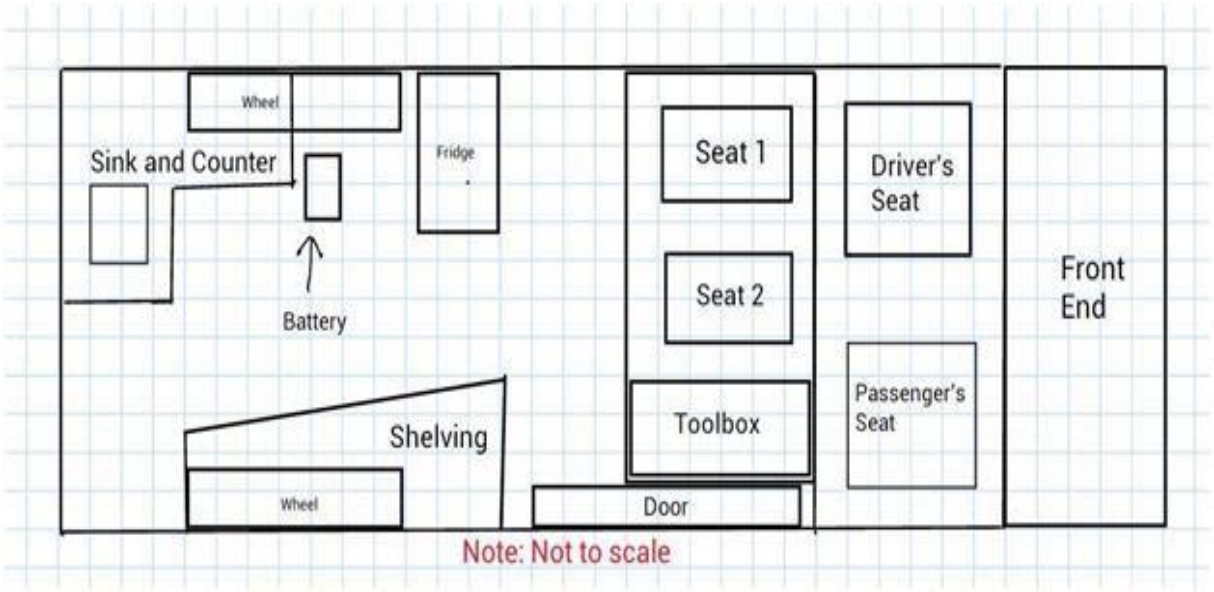

Fig. 1.1 Vehicle Schematic

Fig. 1.2 Medical team in front of the mobile health clinic

Fig. 1.3 Panoramic View of Mobile Clinic in use

Each year, projects developed and led by the leadership institute students are implemented abroad with the intent that the projects become self-sustaining. The mobile health clinic was designed to be culturally and technically appropriate for the communities where the vehicle would be used. There was continuous communication between the leadership institute and the medical director of the main hospital in the region of Ghana where the clinic would be used for outreach. The communication was necessary to avoid the common cycle of healthcare initiatives developed by a donor country that did not consider specific needs of the local population. Through communication and research, engineering students developed a model that they believed would best fit the vehicle's future use. Outdoor lighting capabilities were added, so care could be provided after sunset in remote areas with little to no electricity. In addition, the vehicle and its equipment were designed to be easily operated and maintained by local personnel.

Raising adequate funds for the vehicle, the medical equipment, and the shipping of the clinic involved a multi-organizational network. The engineering students had to work closely with the business students and lead this effort, which was a unique part of the project. The students used a crowdsourcing website and successfully raised most of the funds through this means. Engineering students also led a presentation in front of an organization of hospital CEOs; the board decided to match the amount of funds the students were able to raise on their own. Fig.

1.4 shows a midwife using the portable ultrasound, one of the pieces of equipment that was obtained for the mobile clinic through fundraising efforts.

Fig. 1.4 Midwife using portable ultrasound after learning from the biomedical and mechanical engineering students

In July 2013, the leadership institute team traveled to Ghana to collaborate and help facilitate the initial use of the clinic. This team consisted of a biomedical engineering student, environmental engineering student, mechanical engineering student, and pre-health student. The team spent a week preparing the vehicle for use and teaching engineers and doctors on the technical uses of the vehicle. They explained maintenance along with reasons for engineering certain aspects in order to share their vision of the clinic use. The team also collaborated with the director of the hospital to develop a strategic plan for clinic use in the region.

A medical team composed of staff from a district hospital was the first to take the clinic into the field (along with the institute team). The team included a clinical laboratory scientist, midwife, two community nurses, three nurses for vitals and shots, two pharmacists, an insurance agent, and driver. The hospital's doctor led and organized this team. He was also the one to develop the most effective strategy for seeing patients in periphery villages. For five days, the leadership institute team worked with the medical team to observe how the clinic was being used and to gather ideas for improvement. Each morning, the van was stocked with supplies for the day, which included medication, malaria rapid diagnostic tests, needles, vaccinations, blood pressure cuffs, scales, and insurance folders.

The commute was fifteen minutes to an hour and the vehicle would stop at the village center where the team would introduce itself to the chief. Patients would sit in chairs brought by people in the village and wait to proceed through the line of tables: insurance, vitals, doctor, clinic lab scientist if needed, and then the pharmacist. The process ran smoothly although there were often patients at the end of the day that did not see the doctor and this caused some difficulties.

The leadership institute students were able to form ideas of improvement both in engineering and equipping the vehicle. In the future, additional first-aid capabilities and training will be an addition to the clinic since this was seen as urgently needed. Fig.1.5 shows a biomedical engineering student administering first-aid. The team found supplies at a local store that served the purpose for their time in country.

Fig. 1.5 Biomedical engineering student administering first-aid

The 2014 team will follow-up on the vehicle and the medical teams involved with coordinating usage of the vehicle. There has been continued dialogue with the two doctors who have been involved in the development and use of the vehicle in the field. From this, ideas for further improvement and the sustainability of the project have been obtained.

Results

The clinic served 654 patients in the first week of use; 29% of these patients had treatable malaria. According to the doctor in charge at the time, many patients would have most likely visited the hospital at the point of death when little to nothing could be done to save them. Myalgia, helminthiasis, and respiratory tract infections were also frequent (See Table 1.1). The doctor saw patients that he could do little for in the field. These patients were often underweight or came to the doctor for psychological help. These two may be addressed in future mobile health clinics.

Table 1.1 Tain District Outreach Returns

Disease	Frequency
Malaria	188
Respiratory Tract Infection	52
Gastritis	26
Myalgia	148
Otitis Media	12
Hypertension	8
Diarrhea	8
Peripheral Neuropathy	30
Anorexia	42
Helminthiasis	51
Coryza	15
Anemia	3
Urinary Tract Infection	15
Impetigo	10
Pelvic Inflammatory Disease	2
Sleep Disorders (Insomnia)	5
Others	39

Mobile healthcare makes preventive care and treatment a reality for many more patients and the expansion of mobile healthcare could greatly reduce the number of preventable deaths in the future. It is clear that there is great potential and need for mobile healthcare in Ghana.

The engineering students on the leadership institute team concluded that it would be extremely beneficial to have one person permanently in charge of the mobile health clinic. This person may not be a doctor, but he or she would have a thorough understanding of the clinic's purpose. This leader would have the responsibility of coordinating vehicle usage with interested hospitals, contacting the villages to be visited, communicating with medical teams, proper insurance billing, and stocking of the van. The creation of a mobile health clinic leader would reduce the number of issues with the mobile health clinic and greatly increase its effectiveness. Overall, this leadership role would promote sustainability of the mobile health clinic and further development of the clinic.

During implementation of the mobile health clinic a number of future engineering projects were identified as critical needs. One is the need for many more mobile clinics. Currently, design teams at the university are developing a flexible modular medical equipment package to be inserted into used vehicles readily available in Ghana. The modular packages would contain equipment for diagnostics and treatment. Modular development would greatly reduce shipping and vehicle costs. The increase in mobile health clinics would directly correlate to improved care for those living in the periphery of Ghana.

Another engineering design team at the university is developing a low-cost and simple ventilator and heart annunciator. These devices are being engineered based on the fact that 10-30% of medical equipment donated to developing nations is never used because they are either too

complicated to operate or cannot be maintained.[5] The ventilator will fit the budget of the hospital where it will be used and will be relatively simple to operate, maintain, and repair. Fig. 1.6 shows the ventilator in the design process.

Fig.1.6 Schematic of the Ventilator

Educational Impact

The combination of coursework at the university and the active, discovery based learning in an international setting provides two very valuable methods of learning. The engineering students in both senior design and the leadership institute (the majority of students) gain skills very different than those offered in their typical engineering coursework. While at Michigan Technological University, these students work in multidisciplinary teams of almost all majors, which aids in learning how to communicate with other fields in their professional career.

The engineering students on the leadership institute team gained valuable experience on each step of an engineering project that involved all facets of the engineering design process. The students were in charge of each step of the project including creating a timeline, identifying the needs that the clinic must address, procuring medical equipment, fundraising, designing the most optimized vehicle, building the clinic, and then testing to guarantee that all equipment inside would be able to handle the rougher terrain in Ghana. In addition, the human and social aspects of the project coupled with need to communicate across disciplines and cultures gave the engineering students invaluable experience not often seen in engineers who have been working for several years. As the world continues to become more interconnected, these skills along with the leadership activities are very important in the current market.

Through these experiential international projects the engineering students learned more than just technical skills while working on the mobile health clinic project. It would be safe to say that all of the ABET learning outcomes a through k have been covered thoroughly through this project. The twenty engineering students, plus at least 10 students outside of engineering learned much more than project conception, design and implementation, they improved their communication skills, learned more about the business aspect of project design, learned some of the local

language and customs, and were greatly influenced by the impact of the project in country. The last point is extremely important. The students left the country feeling invested in the project and inspired to create improved models of the clinic.

A paper published in the conference last year compared the education outcomes of three undergraduate student groups at Michigan Technological University working on engineering projects. The students and alumni of the leadership program were surveyed and their responses were compared with the two other major senior engineering design groups at the university. It is important to note that the majority of the leadership program students polled were engineers. Based on these surveys, it was determined that "100% of [leadership institute] students polled responded that their experience abroad significantly improved their general confidence/skills as a leader back home. Only 64% of the [other interest group] responded this way."[6] One reason for this confidence may be attributed to the health clinic project being student-led. Another valuable skill that the leadership institute engineers gained was an improved ability to communicate and navigate a foreign country. According to the survey, "83% of [leadership institute] students indicated that they would be able to communicate sufficiently […] Only 9% of [other interest group] responded this way."[6] Based on this comparison, it may be determined that the experience offered by the leadership program offers engineers a unique learning opportunity.

Conclusion

The mobile health clinic offered a wide variety of opportunities for engineers involved in the project to not only improve their design and build skills but to develop their professional skills to levels not obtainable in the classroom. Currently, engineering students are working to develop modular packages for continued development. Other engineering students are designing low-cost equipment to outfit the vehicle with more capabilities in the future. Engineering students involved in any aspect of these projects will walk away with a unique skillset and widened world outlook on the impact of engineering. Many of the engineering students have been inspired to pursue engineering careers related to healthcare and helping to solve the Grand Challenges facing our world. Large long-term projects involving a significant number of students from multiple disciplines can be implemented at any university that has an engineering or engineering technology school. While the cost of implementing these projects internationally can be prohibitive for many universities, there are many opportunities for domestic projects that could provide many of the same learning outcomes.

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